

India in Space

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1 ISRO

The Indian Space Research Organization (ISRO) is India's national space agency. It was formed on 1969 Aug 15 out of the earlier INCOSPAR (Indian Committee on Space Research) formed in 1962 under the Indian Dept. of Atomic Energy. In 1972 ISRO was moved under a new Dept. of Space.

1.1 Questions

- Launch time for RS-D-1 and RS-D-2 (problems with TLEs)
- Detailed launch time/staging sequences for all SHAR launches
- Detailed trajectories, esp for PSLV-D1 and stage 3 of METSAT
- Mass full and dry for each satellite
- Launch list for Rohini rockets
- GSAT-1 dimensions; IRS-P6 dimensions
- Aryabhata end-of-operations date; same for Bhaskaras
- End of operation dates for IRS? Are they all still working (even if on standby status)
- Images (pictures) of specific satellites e.g. RS-D-1, SROSS-A rather than RS-1, SROSS-C.
- Debris: Use of despinn weights, ejected camera or radiometer covers, etc.
- RS, SROSS, IRS control from ISAC? INSAT, GSAT from MCF.

1.2 ISRO organizations, people and facilities

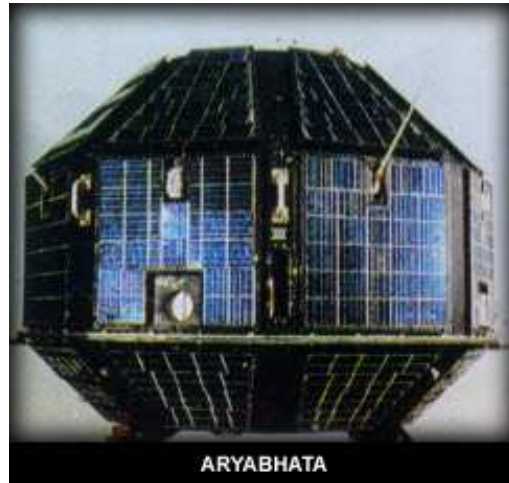
Vikram Sarabhai (1919-1971) was the chair of INCOSPAR and began the Indian space program with sounding rocket launches from TERLS. ISRO was formed on 1969 Aug 15. M.K.K. Menon took over briefly in 1972 followed by Satish Dhawan (1972-84), U.R. Rao (1984-94), Krishnaswamy Kasturirangan (1994-200x?), G. Madhavan Nair (200x?- present). APJ Abdul Kalam was director of the SLV-3 rocket and is now president of India.

D. Narayana Moorthi is director of the launch vehicles program office.

ISRO sites:

VSSC	Trivandrum	Propulsion, launch vehicles
TERLS	Trivandrum	Sounding rockets
LPSC	Mahendragiri	Liquid engines
SDSC	Sriharikota	Orbital launch
ISAC	Bangalore	Satellites
ISTRAC	Bangalore	Tracking
SAC	Ahmedabad	IRS sats?
MCF	Hasan	Insat control

Early ground stations: ESCES-Ahmedabad (ATS-2); Arvi (Pune) INTELSAT; 1975 New Delhi INTELSAT.



1.3 ISRO science satellites

- **Aryabhata** (1975-33A)

The first ISRO satellite was Aryabhata, known as ISS (Indian Scientific Satellite) before launch. It was built by the Indian HAL aerospace company and launched by the Soviet Union from its GTsP-4 cosmodrome at Kapustin Yar.

The polyhedral satellite had a mass of 360 kg. Aryabhata was named after an Indian mathematician of the 5th century AD. The satellite carried astronomical and aeronomy experiments; despite a power problem in the first few days which prompted premature press reports of its demise, the satellite returned some data for at least a year.

Aryabhata			
Date	Time	Event	Orbit
1975 Apr 19	0730	Launch by Kosmos-3M	KY
	0732	Stage 2 burn	
	0737?	Stage 2 burnout	-300? x 600? x 50.7
	0758?	Stage 2 MES-2	
	0758?	Stage 2 MECO-2	
	0800?	Stage 2 sep	96.4 569 x 610 x 50.7
1976 Sep 23?		End of ops	96.47 568 x 610 x 50.7
1981 Mar		End of transmissions?	
1992 Feb 11		reentered	

PAYLOAD

X-ray astronomy 2.5-15.5keV (prop.ctrs)
 Solar neutrons and gamma rays
 Aeronomy experiment (RPA, UV, ion chambers)

- **Bhaskara** (1979-51A)

The Satellite for Earth Observations (SEO) was the second Indian satellite. It was named Bhaskara after launch from Kapustin Yar aboard a Soviet rocket. Bhaskara was built by ISRO/HAL. The 26-faced polyhedron had a mass of 425 kg and was 1.66 m high, 1.55 m diameter. Bhaskara was named after an Indian mathematician of the 7th century AD.

The TV camera suffered from arcing, and was inoperable until outgassing was complete in 1980, when normal operations began.



Bhaskara

Date	Time	Event	Orbit
1979 Jun 7	1030	Launch by Kosmos-3M	KY
	1032	Stage 2 burn	
	1037?	Stage 2 MECO	-300? x 540 x 50.7
	1058?	Stage 2 MES-2	
	1058?	Stage 2 MECO-2	
	1100?	Stage 2 sep	
			95.2 519 x 541 x 50.7
1980		Camera activated	
1981 Mar		End of SAMIR operations	
1981 Aug 1		End of ops?	

PAYLOAD

SAMIR Satellite microwave radiometer 19 + 23 GHz
 TV camera Earth observation in 2 bands (Vis, IR); Failed at launch, OK since 800516.
 DCP Data collection platform (remote met platform data relay)
 Pinhole X-ray sky survey (failed, zero data rate)
 Heat pipe test
 Thermal control tests

• **Bhaskara 2** (1981-115A)

SEO-b, the Bhaskara-2 satellite, was launched on 1981 Nov 20 by Kosmos-3M from Kapustin Yar. The 435 kg ISRO/HAL built satellite was 1.19m high and 1.55m diameter.

Bhaskara 2

Date	Time	Event	Orbit
1981 Nov 20	0830	Launch by Kosmos-3M	KY
	0832	Stage 2 burn	
	0839	Stage 2 MECO-1	
	0839	Stage 2 VECO-1	
	0854?	Stage 2 MES-2	
	0854?	Stage 2 MECO-2	
	0854?	Stage 2 VECO-2	
	0855	Stage 2 sep (T+25:00)	95.20 521 x 543 x 50.6
1983 Jul		End of SAMIR operations	
1984 Apr		End of op life (RAE)	
1991 Nov 30		Reentered	

PAYLOAD

TV cameras (2) 0.54-0.66 micron, 0.75-0.85 micron
 SAMIR Microwave radiometers (3) 19.24, 22.235 and 31.4 GHz
 Data Collection system
 Solar cell experiments
 Thermal control coatings
 Heat pipe test

• **Apple** (1981-57B)

The APPLE (Ariane Passenger Payload Experiment) was India's first experimental comsat, a bridge between the ATS-6 experiments and the Insat series. It was launched on the third Ariane test flight. The 3-axis comsat was 1.2m in diameter and 1.5m high, with a dry mass of 380 kg. The apogee motor was the 4th stage of the SLV-3 launch vehicle and had 272 kg of prop. Launch mass was 670 kg.

There are no NORAD archival elements until Jan 1983 except for four misidentified transfer orbit sets. It's not completely clear the 1983 data are correct, since they show the satellite drifting when it was still in operation.

Apple

Date	Time	Event	Orbit
1981 Jun 19	1233	Launch by Ariane LO3	CSG ELA1
		Stage 1 sep	
	1235:30	Stage 2 TIG	
	1237:25	Coiffe sep	
	1238:00	Stage 3 burn	
	1247	EOI	
	1249:18	CAT/Apple sep from H8	
	1249:37	T+16:38 Meteosat/MTO sep from Apple	
	1250:18	T+17:08? CAT sep from Apple	
1981 Jun 20			635.56 200 x 35997 x 10.5
1981 Jun 21	2243:16	AKM fired by SHAR	GEO 2E dr
1981 Jun 22		Solar panels: 1 deployed, 1 failed temp.	
1981 Jun		TCM	
1981 Jun		TCM	
1981 Jun		Second panel deployed	
1981 Jul 16		On station	GEO 102E
1981 Jul 22		Telecom experiments start	
1981 Aug			GEO 105E
1982 ?		Out of fuel?	
1983 Jan 27			1439.42 35746 x 35956 x 0.3 GEO 47.6W+0.8W
1983 Jun		Drifting	GEO 114E+0.3/d
1983 Sep 15			1439.49 35750 x 35955 x 0.9 GEO 140.1E+0.8W
1983 Sep 20		Turned off	
1988 Apr 18			1439.30 35751 x 35947 x 5.1 GEO 138.6E+0.8W
1999 Apr 28			1439.35 35745 x 35954 x 12.7 GEO 36.3W+0.8W

PAYLOAD

C-band transponder (1)
 Antenna (0.9m)
 SLV-3 AKM

Table 5: Early ISRO satellites

Payload	Name	Launch Veh.	Site	Launch Date	Reentry Date	Dur	Orbit	Designation
ISS	Aryabhata	Kosmos-3M	GTsP-4	1975 Apr 19	1981 Mar		569 x 610 x 50.7	1975-33A
SEO	Bhaskara	Kosmos-3M	GTsP-4	1979 Jun 7	1981 Aug?		519 x 541 x 50.7	1979-51A
SEO-b	Bhaskara 2	Kosmos-3M	GTsP-4	1981 Nov 20	1984 Apr?		521 x 543 x 50.6	1981-115A
APPLE	APPLE	Ariane	CSG	1981 Jun 19	1983 Sep 20		GEO	1981-57B

1.4 Rohini satellites

- **Rohini RS-1** (1979-F03)

The Rohini RS-1 test satellite was launched in Aug 1979 on the first experimental (E) test of the Indian SLV-3 launch vehicle from Sriharikota Island. After a second stage guidance malfunction, the satellite failed to reach orbit despite correct operation of the upper stages. The 35 kg satellite was 0.7m long and 0.6m diameter. Rohini is Sanskrit for Aldebaran, and in Hindu mythology is a wife of Krishna.



Rohini RS-1

Date	Time	Event	Orbit
1979 Aug 10	0228	Launch by SLV-3(E)-01	SHAR
	0233	Stage 2 malfunction T+5:17 Flight termination	
	0238?	Stage 3 burn	
	0238?	Stage 4 burn	
	0238?	Impact Indian Ocean	

PAYLOAD

Flight test instrumentation capsule
Solar array (3W)

- **Rohini RS-1** (1980-62A)

A second RS-1 test satellite was prepared for the next SLV-3 flight, and this time it reached orbit successfully. The 35 kg satellite was similar to the first one.

Rohini RS-1

Date	Time	Event	Orbit
1980 Jul 18	0233	Launch by SLV-3(E)-02	SHAR
		T+0:53 St 1 MECO	
		T+0:54? St 2 MES 44s	
		T+1:38? St 2 MECO	
		Coast to 88 km	
		St 3 MES, 46s	
		St 3 MECO	
		Fairing	

Rohini RS-1

Date	Time	Event	Orbit
		Coast to 305 km	-4742? x 332 x 44.8
	0244:33	T+11:33 St 4 MES, 33s	
	0245:06	T+12:06 St 4 MECO	
	0245	Stage 4 sep	305 x 919 x 45.0
1981 May 20		Reentered? end of tx	

PAYLOAD

Flight test instrumentation capsule
Solar array (3W)

• **Rohini RS-D-1** (1981-51A)

The next satellite was considered the first Rohini Satellite Developmental launch, Rohini RS-D-1. The RS-D-1 satellite carried the Landmark CCD camera for remote sensing tests. It had a 1 km resolution. The intended orbit was 296 x 834 km, but a roll problem during first stage burn led to a low orbit of 183 x 426 km and a premature reentry after only 9 days. The 0.7m long, 0.6m diameter satellite had a mass of 40 kg.

RS-D-1

Date	Time	Event	Orbit
1981 May 31	0500	Launch by SLV-3(E)-03	SHAR
		T+0:53 Stage 1 burnout	
	0501	T+63s Stage 1 roll problem	
		T+1:03? St 2 MES 44s	
	0501	T+1:47? St 2 MECO	
	0502	St 3 MES, 46s	
		St 3 MECO	
		Fairing	
		Coast	
	0511	T+11:33? St 4 MES, 33s	-4839 x 310 x 46.3 ?
	0512	Stage 4 sep	183 x 426
			90.48 186 x 418 x 46.3
1981 Jun 8	0656	End of transmissions	
1981 Jun 8	0656	Reentered over 46N 104W	

PAYLOAD

Landmark CCD camera

• **Rohini RS-D-2** (1983-33A)

The second developmental launch, Rohini RS-D-2, carried an improved CCD payload, with 2 cameras each with 1-m resolution. Mass of RS-D-2 was 41 kg. The launch used the uprated fourth stage meant for ASLV, which had a mass of 512 instead of 360 kg. It had a lightweight glass fiber casing, but published figures actually indicate a lower overall propellant mass fraction of 0.62 instead of 0.73; it's not clear what the correct figures are. Four debris objects were cataloged with the launch.

A contemporary UK publication (G. Falworth's Satellite News) gives the launch time as 0546 UTC, but this is not consistent with the orbital data - I assume below that 0546 UTC is the orbit insertion time.

RS-D-2

Date	Time	Event	Orbit
1983 Apr 17	0534?	Launch by SLV-3(E)-04	SHAR
		T+0:53 St 1 burnout	
		T+0:53 St 2 burn 44s	

RS-D-2

Date	Time	Event	Orbit
		T+1:37 St 2 burnout	
		T+1:37? St 2 sep	
	0535	T+1:38? St 3 burn 46s	
	0536	T+2:24? St 3 burnout	
		Fairing sep	
		T+12m? St 3 sep	
	0546	T+12m? St 4 burn 32s	-4146? x 504 x 46.6
	0546	T+12m? St 4 burnout	
	0546?	St 4 sep	97.0 388 x 852 x 46.6
1984 Sep 24		End of ops	

PAYLOAD

SMART CCDx2 for remote sensing, 1 km resolution
L band tracking beacon 137MHz

• **SROSS A** (1987-F01)

The ASLV (Augmented Satellite Launch Vehicle) first tested in 1987 carried Stretched Rohini Satellites (SROSS) as its test payloads. The first SROSS carried a gamma ray burst detector. The core stage failed to ignite and the 150 kg payload fell in the Bay of Bengal instead of reaching the planned 400 km orbit.

SROSS A

Date	Time	Event	Orbit
1987 Mar 24	0639	Launch by ASLV	SHAR
	0639	Stracons ignite (T+0:00)	
	0641	Core stage ignition failure (T+2:42)	
		Impact Bay of Bengal	

PAYLOAD

LV monitoring
Gamma ray bursts

• **SROSS B** (1988-F03)

The second SROSS also failed when the stage 1 control failed. The strapons burnt out 1.5s early [?] and the TVC could not control the system in the presence of high winds. The vehicle broke up.

SROSS B

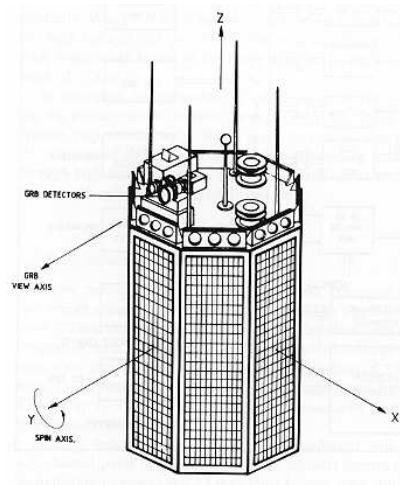
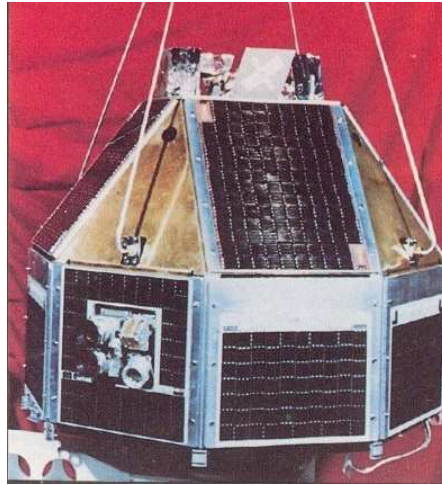
Date	Time	Event	Orbit
1988 Jul 13	0918	Launch by ASLV	SHAR
	0919	Stage 1 guidance failed (T+0:50)	
	0922	Impact Bay of Bengal (T+4:14)	

PAYLOAD

LV monitoring

• **SROSS C** (1992-28A)

The third Stretched Rohini Satellite, SROSS C, was launched on 1992 May 20 by ASLV. It was the first to reach orbit, although the perigee was low due to a stage 3 guidance failure. Mass of SROSS C was 106 kg. The spacecraft's gamma ray burst detector did successfully detect one gamma ray burst seen by GRO. Eight of the 53 triggers seen were candidate bursts, two more of which could be real since GRO was not observing at the time. The detector was sensitive to the 20 keV to 3 MeV range.



SROSS C

Date	Time	Event	Orbit
1992 May 20	0030	Launch by ASLV	SHAR
	0030	Stage 1 core burn (T+0:48)	
	0030	SRB sep (T+0:55)	
	0031	Stage 2 burn (T+1:33) 48 km?	
	0032	Fairing sep (T+2:23), 107 km	
	0032	Stage 3 burn (T+2:28)	
	0033	Stage 3 cutoff (T+3:16), coast	
	0038	Stage 3 sep (T+8:09)	
	0038	Stage 4 burn (T+8:12)	-3854 x 414 x 46.0
	0038	Stage 4 cutoff (T+8:21)	
	0038	Orbit insertion	91.46 248 x 444 x 46.02
	0040?	Stage 4 sep	
1992 Jul 14		Reentered, still op	

PAYLOAD

Gamma ray burst detector, CsI(Na) scintillator
Retarded Potential Analyser, Aeronomy expt

• SROSS C2

(1994-27A)

The 113 kg SROSS C2 satellite was similar to SROSS C with the addition of RCS thrusters for orbit correction [?]. It was launched in May 1994 and was still operating at reentry in 2001, the most successful of the Rohini series.

SROSS C2

Date	Time	Event	Orbit
1994 May 4	0000	Launch by ASLV-D4	SHAR
	0000	Stage 1 core burn (T+0:48)	

Table 14: Rohini

Payload	Name	Launch Veh.	Site	Launch Date	Reentry Date	Dur	Orbit	Designation
RS-1	Rohini RS-1	SLV-3 (1)	SHAR	1979 Aug 10	1979 Aug 10	0	-1000? x 300? x 45?	1979-F03
RS-1	Rohini RS-1	SLV-3 (2)	SHAR	1980 Jul 18	1981 May 20	0.9 yr	305 x 919 x 45.0	1980-62A
RS-D-1	Rohini RS-D-1	SLV-3 (3)	SHAR	1981 May 31	1981 Jun 8	9d	186 x 418 x 46.3	1981-51A
RS-D-2	Rohini RS-D-2	SLV-3 (4)	SHAR	1983 Apr 17	1984 Sep 24	1.4 yr	388 x 852 x 46.6	1983-33A
SROSS A	SROSS A	ASLV	SHAR	1987 Mar 24	1987 Mar 24	0	-6000? x 30? x 46	1987-F01
SROSS B	SROSS B	ASLV	SHAR	1988 Jul 13	1988 Jul 13	0	-6000? x 20? x 46	1988-F03
SROSS C	SROSS C	ASLV	SHAR	1992 May 20	1992 Jul 14	55d	248 x 444 x 46.0	1992-28A
SROSS C2	SROSS C2	ASLV	SHAR	1994 May 4	2001 Jul 12	7.1 yr	433 x 922 x 46.0	1994-27A

1.5 INSAT program

INSAT was the Indian National Satellite series, operated by ISRO and managed by the Dept. of Space, the Dept. of Posts and Telecommunications and the Department of Meteorology. The INSAT 1 series combined communications, meteorology and direct broadcast TV payloads.

The main slots used by ISRO are 74E, 83E and 93E; a history of ISRO orbital slot usage is given below.

Orbital slot	Date	Satellite
48E	2001 Apr - 2002 Apr	Insat 2A
	2002 Apr - 2003 Jun	Insat 2C
	2003 May - (2004+)	GSAT-2
55E	1998 Jan - 2003 Jun	Insat 2DT
72E	1982 Jun- 1982 Sep	Insat 1A
	1997 Jun - 1997 Oct	Insat 2D
74E	1983 Nov - 1992 Apr	Insat 1B
	1992 Aug - 2001 Jan	Insat 2A
	1999 Sep - 2002 May	Insat 1D
	2002 Feb - (2004+)	Insat 3C
82E	2003 Oct - (2004+)	Insat 2DT
83E	1990 Jun - 1999 Jul	Insat 1D
	1999 Apr - (2004+)	Insat 2E
	2000 Apr - (2004+)	Insat 3B
93E	1988 Aug - 1989 Dec	Insat 1C
	1992 May - 1993 Aug	Insat 1B
	1993 Aug - 2000 Nov	Insat 2B
	1995 Dec - 2002 Mar	Insat 2C
	2003 Apr - (2004+)	Insat 3A
111E	2002 Apr - 2004 Jan	Insat 2B

• Insat 1A (1982-31A)

Insat 1A was built by Ford Aerospace for ISRO. It was launched on 1982 Apr 10 by Delta 3910/PAM-D. Insat 1A failed in 1982 Sep, only a few months into the mission, when attitude control propellant was depleted.

After launch, the solar panel and the C-band antenna did not deploy. After 12 days the C-band system was activated but the solar panel problem affected many of the systems; the VHRR imager failed in August, and attitude control was lost in September.

The satellite was lost by US tracking in 1984; an elset in 1992 is probably a misidentification and even the 1984 set has a suspiciously low inclination. Regular element sets resumed in 1999 showing the satellite drifting in the geostationary band.

The 1149 kg satellite had a 2.2 x 1.4 x 1.6 m bus with 1 solar panel and 1 balancing 12.1m boom solar wind paddle; span is 19.4m. The satellite can carry up to 630 kg of prop.

Insat 1A

Date	Time	Event	Orbit
1982 Apr 10	0647	Launch by Delta 3910/PAM-D T+0:57 SRM 1-6 off	CC LC17

Insat 1A

Date	Time	Event	Orbit
		T+1:02 SRM 6-9 on	
		T+1:10 SRM 1-3 sep	
		T+1:24 SRM 4-6 sep	
		T+1:59 SRM 6-9 off	
		T+2:05 SRM 6-9 sep	
		T+3:43 MECO	
	T+3:45		
	St 1 sep		
		T+3:51 SES-1 5:04	
		T+4:01 Fairing	
	0655	T+8:55 SECO-1	
		T+18:45 spinup	
	0705	T+18:47 St 2 sep	-579? x 228 x 28.1
	0706	T+19:26 TES 86s	
	0707	T+20:52 TECO at 17W 0N	
	0717	Stage 2 reentry over 17E 18S?	
	0727	T+40? PAM sep (20 min after burnout)	
1982 Apr 10	1230		631.33 223 x 35776 x 28.1
1982 Apr 11		LAM-1 Apogee burn	
1982 Apr 12		LAM-2 burn	
1982 Apr 12			1416.73 35031 x 35781 x 0.5 GEO 75.8E+4.9E
		Solar sail failed to deploy	
1982 Apr 15		LAM	
1982 Apr 22		C-band deployed	
1982 May 4			1436.08 35394 x 36178 x 0.5 GEO 73.5E
1982 Jun 25			1436.03 35393 x 36176 x 0.4 GEO 72.6E
1982 Jun 25		On station	GEO 72.4E
1982 Aug 13		VHRR failed	
1982 Sep 4		Failed, attitude control lost	
1982 Sep 6		Abandoned	
1983 Dec 29		Drifting	1434 GEO 89Wdr
1984 May 3			1434.14 35561 x 35935 x 0.1 GEO 19.3W+0.5E
1999 Nov 28			1435.87 35676 x 35887 x 12.6 GEO 28.4E+0.0E
2000 Jul 23			1434.75 35692 x 35828 x 12.8 GEO 84.8E+0.3E
2004 Jul 5			1437.17 35761 x 35853 x 13.6 GEO 49.4E+0.3W

PAYLOAD

Solar panel
Solar paddle
Comms channels (12) (including 2 DBS channels)
VHRR (vis/ir)
Met data relay channel
R-4D-11 apogee engine, 490N

• **Insat 1B** (1983-89B)

The second Insat was launched with a PAM-D from the Space Shuttle Challenger on mission STS-8. No archival orbital data are available from 1984 Mar to 1987 Mar. The satellite was replaced by Insat 1D in 1990 and retired in 1993 after the launch of Insat 2B.

Insat 1B

Date	Time	Event	Orbit
1983 Aug 31	0748:54	Insat 1 deploy from OV-099	
	0749	Hit by small fragment secs after deploy	

Insat 1B

Date	Time	Event	Orbit
	0833	PAM-D burn	
	0834	PAM-D burnout	
	0914?	PAM-D sep	
		Solar panels failed to deploy	
1983 Sep 1			686.1 295 x 38940 x 25.0
1983 Sep 1			659.31 288 x 37141 x 24.3
1983 Sep 2		LAM-1	808.07 7615 x 37104 x 10.5
1983 Sep 7			1412.1 33429 x 37158 x 0.5
1983 Sep 9			1430.9 34084 x 37291 x 0
1983 Sep 10		Solar panels deployed	1416.35 33556 x 37242 x 0.5
1983 Nov 14		On station	1436.08 35782 x 35798 x 0 GEO 74.1E
1984 Mar 26			1436.17 35767 x 35808 x 0.0 GEO 73.9E
1987 Mar 3			1436.18 35752 x 35824 x 0.1 GEO 73.8E
1989 Sep 11			1436.09 35742 x 35830x 0.1 GEO 74.0E
1990 Jul 17		Moved to spare status	
1991 Jan 30			1436.10 35769 x 35804 x 1.3 GEO 73.9E
1992 Mar 4			1435.96 35769 x 35798 x 2.3 GEO 74.7E
1992 Apr 8		mv out	1435.07 35739 x 35794 x 2.4 GEO 87.2E+0.25E
1992 May 30		mv in	1436.13 35765 x 35808 x 2.5 GEO 93.5E
1992 Dec 14			1436.12 35760 x 35813 x 3.0 GEO 93.6E
1993 Jul 29			1436.16 35761 x 35814 x 3.5 GEO 93.4E
1993 Aug 3?		orbit raise, retired	
1993 Aug 9			1437.63 35802 x 35830 x 3.5 GEO 90.7E+0.4W
1996 Apr 18			1436.81 35412 x 36188 x 5.4
1999 Apr 17			1437.05 35777 x 35833 x 7.4

PAYLOAD

Solar panel
Solar paddle
C-band Comms channels (12) (including 2 DBS channels)
VHRR (vis/ir)
Met data relay channel

• **Insat 1C** (1988-63A)

The third Insat was launched in 1988 on an Ariane 4 but was largely a failure. A month after launch, a power system failure crippled half of the C-band payload transponders and the two S-band transponders. The meteo imager and data relay operated until late 1989, but on 1989 Nov 22 the satellite lost Earth lock and was abandoned.

Insat 1C

Date	Time	Event	Orbit
1988 Jul 21	2312	Launch by Ariane	
		PAP sep	
		MECO	
		T+2:23 St 1 sep	
		T+2:23 Stage 2 burn	
		T+3:41 Fairing	
		T+4:29 St 2 MECO	
		T+4:34 St 2 sep	
	2316	T+4:38 Stage 3 burn	
	2328?	T+16:39? St 3 MECO	
		T+17:56? spinup	
	2330?	T+18:23? Insat sep	638.6 282 x 36089 x 7.3
	2332?	T+20:04 Sylva 4400 upper section sep	

Insat 1C

Date	Time	Event	Orbit
	2334?	T+21:44? ECS sep	
1988 Jul 22		LAM burn?	
1988 Jul 23		LAM burn?	
1988 Jul 24			1445.65 35958 x 35988 x 0.2 GEO 103.E+2.4W
1988 Aug 6			1440.13 35758 x 35973 x 0.2 GEO 86E-1/d
1988 Aug 8			1434.8 35707 x 35816 x 0.2 GEO 93E+0.3/d
1988 Aug		Power systems partially failed	
1988 Aug 16			1436.15 35763 x 35811 x 0.1 GEO 93.5E
1988 Oct 16			1436.17 35764 x 35811 x 0.0 GEO 93.2E
1989 Nov 25		Last mv, lost Earth lock	
1989 Dec 10			1436.07 35746 x 35825 x 0.2 GEO 93.9E
1989 Dec		Drifting	
1990 Feb 12			1436.38 35754 x 35829 x 0.3 GEO 91.9E
1991 Feb 3			1435.95 35747 x 35819 x 1.2 GEO 56.4E+0.03E
1995 May 25			1435.75 35762 x 35797 x 4.8 GEO 59.0E+0.08E
1999 Jun 10			1436.00 35754 x 35815 x 7.3 GEO 56.0E+0.02E

PAYLOAD

Solar panel
Solar paddle
Comms channels (12) (including 2 DBS channels)
VHRR (vis/ir)
Met data relay channel

• **Insat 1D** (1990-51A)

The final Insat 1 satellite was launched by a Delta from Cape Canaveral in 1990. It was still operating in 1999, but in May 2002 it stopped stationkeeping and is presumed abandoned.

After launch, Insat 1D failed to separate from the PAM-D stage [?] and the separation was commanded by Insat MCF-Hassan.

Insat 1D

Date	Time	Event	Orbit
1990 Jun 12	0552	Launch by Delta 4925	CC LC17
	0556	SRM sep	
	0556	Thor MECO	
	0556	Thor sep	
	0556	Stage 2 burn	
	0602?	Stage 2 SECO-1	
	0614?	Stage 2 SES-2	
	0615?	Stage 2 SECO-2	133? x 414? x 27.3
	0616	Stage 3 burn	
	0617	Stage 3 burnout	133 x 39749 x 27.2
		Spacecraft tumbling	
	0637	PAM-D sep	
	0645?	Stage 2 depletion	258 x 415 x 27.3
1990 Jun 14	1130?	Apogee at 92E	
1990 Jun 14	1130?	LAM?	
1990 Jun 15	1100?	Apogee at 100E	
1990 Jun 15			1455.99 32388 x 39962 x 0.4 GEO 83.2E+4.9W
1990 Jun 22			1435.81 35754 x 35807 x 0.2 GEO 83.4E
1990 Jun 30			1436.17 35769 x 35806 x 0.2 GEO 83.1E
1992 Aug 1			1436.14 35775 x 35800 x 0.1 GEO 83.0E
1996 Oct 8			1436.16 35774 x 35800 x 0.1 GEO 83.0E
1999 Jun 16			1436.13 35769 x 35804 x 1.1 GEO 83.0E

Insat 1D

Date	Time	Event	Orbit
1999 Jul		mv out	1436.70 35781 x 35815 x 1.3
1999 Sep 22			1436.28 35767 x 35813 x 1.3 GEO 74.3E
2000 Jun 13			1436.14 35754 x 35821 x 1.9 GEO 73.4E
2002 Apr 4			1436.01 35725 x 35844 x 3.4 GEO 74.4E
2002 May		Begin drift	
2002 May 8			1436.24 35727 x 35853 x 3.6 GEO 72.7E+0.05W
2003 Sep 4			1436.01 35716 x 35853 x 4.7 GEO 80.7E
2004 Jul 22			1436.25 35712 x 35866 x 5.5 GEO 70.6E+0.05W

PAYLOAD

Solar panel
Solar paddle
Comms channels (12) (including 2 DBS channels)
VHRR (vis/ir)
Met data relay channel

• **Insat 2A** (1992-41A)

The second generation Insat was built in-house by ISRO. Similar in design to Insat I, the satellite was box-shaped with a solar array on one side and a boom on the other with a conical solar sail. The spacecraft mass was 1906 kg full, 1162 kg GEO, 911 kg dry. Size is 1.9 x 1.7 x 1.7m with 23m span. The satellite was stationed over 74E until 2001, and was retired in 2002.

Insat 2A

Date	Time	Event	Orbit
1992 Jul 9	2242	Launch by Ariane 44L	
		PAL sep	
		Stage 1 sep	
		Stage 2 sep	
		H-10 burn	
	2259	H-10 cutoff (T+17:50)	
	2301	Insat 2A sep from SPELDA (T+19:23)	
	2303	SPELDA sep from H10 (T+21:13)	
	2305	Eutelsat sep (T+22:59)	
	2305	H-10 avoidance burn (T+23:24)	
1992 Jul 11	0100?	LAM1	
1992 Jul 12			1109.00 22389 x 35835 x 0.3
1992 Jul 13	0800?	LAM3 burn	
1992 Jul 25			1421.89 35208 x 35807 x 0.21 GEO 65.44E+3.6/d
1992 Jul 28			1438.54 35537 x 36131 x 0.19 GEO 72.76E- 0.62/d
1992 Aug 24			1436.08 35770 x 35802 x 0.2 GEO 74.0E
1993 Jun 28			1436.10 35766 x 35806 x 0.0 GEO 73.9E
1996 May 1			1436.08 35777 x 35795 x 0.1 GEO 74.1E
1999 Jun 15			1436.09 35739 x 35833 x 1.6 GEO 73.9E
2001 Jan 9			1436.24 35710 x 35868 x 2.9 GEO 73.9E
2001 Jan		Move to 48E	
2001 Mar 16			1437.42 35782 x 35842 x 3.0 GEO 51.7E+0.3W
2001 Apr 4			1436.46 35754 x 35832 x 3.0 GEO 48.5E+0.1E
2001 Jun 5			1436.07 35751 x 35820 x 3.2 GEO 48.1E
2002 Feb 21			1436.03 35772 x 35798 x 3.8 GEO 48.0E
2002 Apr 28		mv out	

Insat 2A

Date	Time	Event	Orbit
2002 May		Retired	1437.68 35791 x 35844 x 4.0
2004 Feb 15			1437.66 35791 x 35842 x 5.5

PAYLOAD

C-band transponders (18)
S-band transponders (2)
C/S-band dishes 1.8m size
VHRR Meteo package, 2 km vis/8 km IR
CNES SAR package
ISRO LAM liquid apogee motor

• **Insat 2B** (1993-48B)

The Insat 2B satellite had a launch mass of 1931 kg. 916 kg dry. It flew as lower passenger aboard Ariane flight V58 and after delivery to GTO on 1993 Jul 22, reached the geostationary ring around Jul 29. By early August in was on station at 93E.

The satellite was retired from main service in 2000 Nov after problems when its attitude fuel was exhausted following an Earth lock loss episode. However, it did continue operating until 2004. Controllers began raising the orbit of the satellite on 2004 Jan 6, although all fuel was depleted early in the operation.

Insat 2B

Date	Time	Event	Orbit
1993 Jul 22	2258:55	Launch by Ariane 44L V58	CSG
		PAL sep (T+1:07; times from H.1A)	
	2301?	Stage 1 sep (T+2:28)	
	2302?	Fairing sep (T+3:35)	
	2303?	Stage 2 sep (T+4:39)	
	2304?	H-10+ ignition (T+5:47)	
	2317?	H-10+ shutdown (T+18:17)	
	2319?	Hispasat 1B sep (T+20:32)	
	2322?	SPELDA top sep (T+23:21)	
	2323?	Insat sep (T+24:55)	
	2324?	H10+ sep mvr (T+25:25)	
		631.16 199 x 35790 x 7.0	
1993 Jul 23		LAM-1	743.82 7692 x 33939 x 1.1
1993 Jul 24		LAM-2	911.20 13782 x 35729 x 1.2
1993 Jul 29	0400?	LAM-3	
1993 Jul 31	2121		1429.29 35435 x 35871 x 0.21 GEO 88.3E+1.7E
1993 Aug 2	2200		1434.79 35706 x 35816 x 0.22
1993 Aug 5	1900		1436.16 35769 x 35807 x 0.20 GEO 93E
1993 Sep 27			1436.15 35750 x 35824 x 0.1 GEO 93.5E+0.01W
1996 May 20			1436.05 35768 x 35803 x 0.1 GEO 93.6E
1999 Oct 13			1436.14 35772 x 35802 x 0.1 GEO 93.5E
2000 Nov 4		Out of main service	
2002 Feb 24			1436.06 35764 x 35806 x 1.2 GEO 93.6E
2002 Mar		move out	
2002 Apr 12			1436.11 35749 x 35823 x 1.4 GEO 111.5E
2002 Jul 6			1436.13 35744 x 35829 x 1.6 GEO 111.6E-0.01W
2004 Jan 4			1436.32 35776 x 35805 x 2.9 GEO 111.0E-0.07W
2004 Jan 6		Orbit raise Fuel depleted	
	1525	Switched off	
2004 Feb 14			1440.62 35801 x 35949 x 3.0

PAYLOAD

C-band transponders (18)
 S-band transponders (2)
 Meteo package
 CNES SAR package
 ISRO LAM liquid apogee motor

• **Insat 2C** (1995-67B)

The third in the Insat 2 series carried the C and S band transponders, but the meteo package was replaced by Ku-band transponders for television broadcast. Mass of Insat 2C was 2050 kg at launch, 980 kg dry. The bus was 2.3 x 2.5 x 2.7 m in size, with 14.6m solar panel span. It was stationed at 93.5E until 2002, colocated with Insat 2B; then it moved to 48E for Ku-band payload tests. Insat 2C ran out of stationkeeping propellant on 2002 Sep 7 and after several further months of use was retired in 2003 Jun, using the low thrust of residual gas in the thrusters.

Insat 2C			
Date	Time	Event	Orbit
1995 Dec 6	2323	Launch by Ariane	
	2326	Stage 1 sep	
	2326	Stage 2 on	
	2327	Fairing 01 sep	
	2328	Stage 2 off (T+5:42)	
	2328	Stage 3 on (T+5:48)	
	2340	H-10-III cutoff (T+17:06)	
	2344	Telecom 2C sep from Mini-Spelda (T+21:18)	630.1 224 x 35712 x 6.8
	2347	Mini-Spelda sep (T+24:18)	
	2349	Insat 2C sep (T+26:18)	
1995 Dec 7		Stage 3 avoidance burn	
1995 Dec 7			630.23 224 x 35719 x 7.0
1995 Dec		LAM burn	
1995 Dec		LAM burn	
1995 Dec 19			1435.30 35723 x 35818 x 0.1 GEO 92.5E
1996 Jan 24			1435.81 35756 x 35805 x 0.0 GEO 93.6E
1999 Oct 15			1436.10 35764 x 35808 x 0.1 GEO 93.5E
2002 Mar 4			1436.15 35779 x 35795 x 0.4 GEO 93.5E
2002 Apr 3		mv in	
2002 Apr 11			1436.10 35757 x 35815 x 0.4 GEO 48.1E
2002 Sep 7		Out of propellant	
2003 Jun 10		Begin residual gas thrusting	GEO 47E
2003 Jul 1			1439.19 35812 x 35883 x 1.1
2003 Jul 24		End of re-orbiting operation	
2003 Jul 28			1443.06 35913 x 35933 x 1.2

PAYLOAD

C-band transponders (18)
 S-band transponder, mobile services
 Ku-band transponders (4)
 ISRO LAM liquid apogee motor

• **Insat 2D** (1997-27B)

Insat 2D, which like Insat 2C was the communications-only variant, was stationed at 74E. Insat 2D joined the Indian National Satellite System. Primary coverage area is Indian subcontinent, with extended coverage area over Mideast to SE Asia. Control from Insat Master Control Facility, Hassan/Karnataka.

Insat 2D mass was 2079 kg launch, 1270 kg BOL, 999 kg dry. Bus was 1.7 x 1.9 x 2.7 m with a 14.70m span, like Insat 2C.

The satellite failed in October 1997. On October 1 it lost earth lock, possibly as a result of a solar storm; after several days in safemode it lost power and was abandoned.

Space Command tracked the satellite on station until late Nov 1977, and then in 1998 it was tracked in a subsynchronous orbit. It is not clear when the orbital altitude was lowered.

Meanwhile, Arabsat 1C was bought from the Arabsat consortium, renamed Insat-2DT, and moved to 55E to serve as a replacement.

Insat 2D			
Date	Time	Event	Orbit
1997 Jun 3	2320	Launch by Ariane 44LP V97	CSG ELA2
	2323	Stage 1 sep T+3:32	
	2324	Fairing sep T+4:48	
	2325	Stage 2 sep T+5:42	
	2338?	Stage 3 MECO	
	2341	H10-3 sep from Inmarsat T+21:17	
	2344	Mini Spelda top sep T+24:17	
	2346	H10-3 sep from Insat T+26:17	
1997 Jun 4			635.14 249 x 35945 x 7.0
1997 Jun 5			629.46 218 x 35685 x 7.0
1997 Jun 6?		LAM-1	
1997 Jun 10?	LAM-2		
1997 Jun 11			1430.54 35474 x 35881 x 0.2 GEO 66.4E+1.4E
1997 Jun 16			1434.43 35720 x 35787 x 0.2 GEO 72.6E+0.4E
1997 Jun 16			1436.05 35742 x 35829 x 0.2 GEO 72.6E
1997 Sep 16			1436.14 35726 x 35849 x 0.2 GEO 72.3E
1997 Oct 1		Earth lock lost	
1997 Oct 4		Power failure	
1997 Oct 5		Satellite abandoned	
1997 Nov 22			1436.09 35713 x 35859 x 0.4 GEO 74.1E
1997 Dec?		Move out of GEO	
1998 Jan 15			1374.22 33155 x 35977 x 0.3
1999 Oct 16			1374.15 33166 x 35963 x 1.6

PAYLOAD

C-band transponders FSS (12), 50W
 C-band transponders FSS wideband (6), 50W
 S-band transponder, BSS, 70W
 S-band and C-band transponders, 2, MSS mobile services, 70W
 Ku-band transponders, FSS (3), 20W
 ISRO LAM liquid apogee motor

• Insat 2E (1999-16A)

Intelsat leased 11 of 2E's C-band transponders in 1995. Mass is 2550 kg full, 1270 kg BOL, 1146 kg dry. Size is 1.93 x 1.77 x 2.3m, span is 24.7m. The advanced VHRR weather radiometer failed in late 1999.

Insat 2E			
Date	Time	Event	Orbit
1999 Apr 2	2203	Launch by Ariane 42P	
		T+1:34 PAP sep	
		T+3:29 Stage 1 sep	
		T+4:14 Fairing sep	
		T+5:37 Stage 2 sep	
	2208	T+5:42 Stage 3 burn	
	2221	T+18:41 stage 3 MECO	
	2224	T+21:03 Stage 3 sep	
		T+23:02 End of V117	

Insat 2E

Date	Time	Event	Orbit
1999 Apr 3			634.92 256 x 35927 x 0.2
1999 Apr 4	0021	LAM-1, 16min	
1999 Apr 5	2015	LAM-2, 1:00:05	
1999 Apr 8	0705	LAM-3 33min	
1999 Apr 8			1429.94 35476 x 35855 x 0.2
1999 Apr 10		LAM-4	
1999 Apr 11		Solar array deploy	
1999 Apr 25			1436.09 35767 x 35805 x 0.1 GEO 83.0E
1999 Sep ?		VHRR failed	
1999 Nov 8			1436.10 35774 x 35798 x 0.1 GEO 83.0E
2004 Jul 23			1436.10 35780 x 35792 x 0.1 GEO 83.0E

PAYLOAD

VHRR radiometer, water vapor profile
 CCD imager
 C-band antenna, with Intelsat China/Australia footprint.
 C-band transponders (10), 32W, 36MHz wide
 C-band transponders (7), 60W, 36/72MHz
 LPSC ISRO-LAM, 440N MMH/N2O4

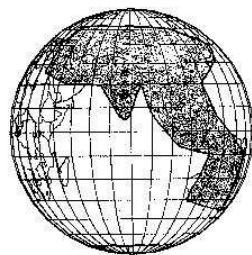
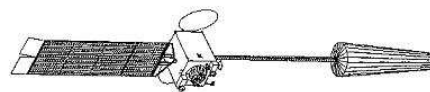


Figure 1: Insat 2E: illustration of deployed mast

• **Insat 3B**

(2000-16B)

Launch by Ariane 5 in 2000; the first of the new Insat 3 series. Mass 2070 kg launch 970 kg dry, 1.9 x 1.7 x 1.7 m with 14.7m span.. Data, telephone and broadcast services for India. Control from Insat MCF, Hassan.

The Ariane 5 EPC has an apogee around 200 km and reenters over the Galapagos.



Figure 2: Insat-3B in ground test

Insat 3B			
Date	Time	Event	Orbit
2000 Mar 21	2328:30	Launch by Ariane 5	CSG ELA3
		T+7s liftoff	
		T+2:25 EAP sep	
		T+3:19 Fairing	
	2338	T+9:51 MECO	
	2338	T+9:57 sep	26 x 1200? x 7.0 45 x 1368 x 7.7
		T+10:04 EPS burn	
		T+26:42 EPS MECO	674 x 35479 x 7.05
	2355	T+27:57 Asiastar sep	
	2359	T+31:08 SYLDA-5 sep	
2000 Mar 22	0002	T+34:39 Insat 3B sep	638.23 583 x 35771 x 7.0
	0050?	EPC impact Pacific	
2000 Mar		LAM-1	
2000 Mar 24			1337.62 32011 x 35660 x 0.3
2000 Mar 24	1750?	LAM-2	1414.88 32624 x 38116 x 0.2
2000 Mar 26	0624	LAM-3 3:09	1425.16 35507 x 35637 x 0.1 GEO 73.7E+2.7/d
2000 Mar 27		Solar array deployment	
2000 Apr 16			1436.07 35740 x 35831 x 0.0 GEO 83.0E
2000 May 26			1436.12 35770 x 35803 x 0.0 GEO 83.0E
2004 Feb 14			1436.10 35759 x 35813 x 0.1 GEO 83.0E

PAYLOAD

C-band transponders, 17
 Ku-band transponders, 6
 S-band transponders, 3
 Ku beacon
 440N LAM

• **GSAT-1**

(2001-15A)

The GSAT-1 experimental comsat is a test payload for ISRO's GSLV rocket, which is derived from PSLV. The GSLV stage 3 has a LOX/LH2 RD-56M engine. Launch was from SHAR in 2001.

GSAT was to have demoed digital audio and compressed TV from 48E; The satellite is similar to Insat-2, with a single solar array and a counterweight solar sail boom.

Control from Hassan. Mass is 1540 kg. The GSLV flight was a little underpowered, and the satellite fuel was depleted reaching near-GEO.

GSAT-1			
Date	Time	Event	Orbit
2001 Mar 28	1017	GSLV SOM ignition	SHAR
		SOM abort on pad	
2001 Apr 18	1013	T-4s PSOM ignite	
2001 Apr 18	1013	Launch	
		T+1:40 St 1 burnout 2.63 km/s	
		T+2:40 St 2 MES	
		T+2:42 PSOM cutoff at 75 km	
		T+4:40 Fairing sep	
		T+5:07 St 2 MECO 126 km, 5.18 km/s	
		T+5:14 St 2 sep	-4541 x 127 x 19?
		T+5:14? St 3 MES 11:33	
		T+16:47? St 3 MECO 195 km, 10.17 km/s	
	1030	T+17:16 St 3 sep	
		St 3 passivation	
2001 Apr 18			557.93 166 x 31977 x 19.3
2001 Apr 19	0023	LAM-1	3000 x 32000 x 19.3
2001 Apr 19	1543	LAM-2 4min 75m/s	3000 x 35880 x 13.3 (ISRO)
2001 Apr 20			724.86 4864 x 35838 x 11.5
2001 Apr 20	2020	LAM-3 600m/s	11900 x 35830 x 5.5
2001 Apr 23		LAM-4	
2001 Apr 25			1384.12 33800 x 35725 x 1.0
2001 Apr 26			1384.54 33804 x 35738 x 1.0
2003 Jan 26			1386.99 33853 x 35786 x 0.5
2004 Feb 14			1386.97 33868 x 35770 x 1.5

PAYLOAD

S-band transponder, 2 bands
C-band transponders, 2

• **Insat 3C**

(2002-02A)

Mass 2750 kg launch, 1050 kg dry. Size 2.8 x 1.7 x 2.0 m with 15.4 m span. This was the last planned Ariane 42L launch, and used a trajectory with a high initial perigee of 570 km. 3C will be placed at 74E.

Insat 3C			
Date	Time	Event	Orbit
2002 Jan 23	2347	Launch by Ariane 42L	CSG ELA2
		T+2:19 PAL sep	
		T+3:13 St 1 sep	
		T+3:16 St 2 MES	
		T+3:39 Fairing	
		T+5:25 St 2 sep	
		T+5:30 St 3 MES	
		T+12:15	-2900 x 507
2002 Jan 24	0005	T+18:30 MECO	

Insat 3C

Date	Time	Event	Orbit
	0007	T+20:52 Insat 3C sep T+22:52 End of V147	
2002 Jan 24			638.54 580 x 35790 x 4.0
2002 Jan 25		LAM-1	817.02 9363 x 35780 x 1.7
2002 Jan 27		LAM-2	1015.11 18365 x 35794 x 0.8
2002 Jan 30	?	LAM-3	1428.37 35490 x 35779 x 0.19 GEO 67E+2E/d
2002 Feb 1	Deployment of solar panels		
2002 Feb 9		LAM	1435.90 35760 x 35804 x 0.1 GEO 74E
2002 Jul 20			1436.11 35767 x 35805 x 0.0 GEO 74.0E
2004 Jul 21			1436.10 35771 x 35802 x 0.0 GEO 74.0E

PAYLOAD

S-band transponders, 2
C-band transponders, 30
L-band? Mobile comms transponder.

• **Kalpana-1**

(2002-43A)

The ISRO Metsat was launched by modified PSLV in Oct 2002 to GEO. It replaces the failed payloads on Insat 2E and Insat 2B. Mass 1060 kg including 560 kg of prop. Built by ISRO SC Bangalore and control from Hassan MCF; will station at 74E.

PSLV-C4 uses an improved third stage motor. Burn time 112s, thrust 119t at sea level. Analysis indicates the third stage must have been close to reaching orbit on this direct ascent mission.

Prior to this launch, the SHAR launch site was renamed the Prof Satish Dhawan Space Center. METSAT-1 was renamed KALPANA-1 on 2003 Feb 6 after the loss of Kalpana Chawla on Columbia.

METSAT

Date	Time	Event	Orbit
2002 Sep 12	1023:40	Launch by PSLV C4 T+0:25 PSOM 3-4 burn T+1:06 PSOM 1-2 sep T+1:30 PSOM 3-4 sep T+1:52 Stage 1 sep T+1:53 Stage 2 MES T+2:36 Fairing T+4:39 Stage 2 sep	SHAR
	1028:20?	T+4:40 Stage 3 burn	
	1030?	Stage 3 MECO	20? x 300? x 17.7
	1035?	Stage 4 burn	
	1042?	Stage 4 MECO	
	1044:31	T+20:51 PS4 sep	218 x 34700 x 17.67
2002 Sep 13	0135	LAM-1 31:48	12100 x 34500 x 5
2002 Sep 14	0558	LAM-2?	34400 x 34500 x 0.3
2002 Sep 15	0440	LAM 31s	34500 x 35676
2002 Sep 17	0000		1399.70 34508 x 35633 x 0.5
2002 Sep 19		VHRR switched on	
2002 Oct 9			1436.12 35771 x 35802 x 0.5 GEO 74.0E
2003 Feb 6		Renamed Kalpana-1	
2004 Feb 14			1436.09 35767 x 35805 x 0.1 GEO 74.0E

PAYLOAD

VHRR, 3-band
DRT Data Relay Transponder



• **Insat 3A**

(2003-13A)

Inast-3A was built by ISRO/Bangalore and launched in 2003 by Ariane 5, to be stationed at 93.5E. Mass 2958 kg launch 1350 kg dry, size 2.8 x 1.7 x 2.0 m with 24.4 m span, box + 1 panel + boom. Of 1603 kg prop, 505 kg left after LAM-3. During launch, Insat 3A is on top of a Sylda 5C and under a Medium fairing 5.8m high 4.6m dia.



Insat 3A

Date	Time	Event	Orbit
2003 Apr 9	2252:19	Launch by Ariane 5G	CSG ELA3
		T+2:21 EAP sep	
		T+3:10 Fairing sep	
	2301	T+9:56 EPC MECO	
	2302	T+10:02 EPC sep 206	-41 x 1561 x 6.0
	2302	T+10:09 EPS burn	
	2319	T+27:12 EPS MECO	
	2319	T+27:22 Insat 3A sep	
	2324	T+32:48 Sylda 5 sep	
	2330	T+38:43 Galaxy 12 sep	
		T+55:02 EPS depletion complete	
	2340	EPC apogee 1561 km	

Insat 3A

Date	Time	Event	Orbit
2003 Apr 10	0022	EPC entry	
2003 Apr 10			642.81 861 x 35726 x 2.0
2003 Apr 11		LAM-1	
2003 Apr 11	0300		864.01 11483 x 35859 x 1.0
2003 Apr 12	0630	LAM-2	32750 x 36000 x 0.1
2003 Apr 14	0409	LAM-3 3:41	
2003 Apr 15		Deploy solar arrays and antennas	
2003 Apr 16		Deploy N solar sail/boom	
		In 3-axis mode	
2003 Apr 17		CCD camera on	
2003 Apr 18		VHR on	
2003 Apr 18			1432.13 35565 x 35851 x 0.0
2003 May 13			1436.14 35772 x 35802 x 0.1 GEO 93.5E
2004 Feb 14			1436.15 35773 x 35801 x 0.0 GEO 93.5E

PAYLOAD

VHRR

C-band transponders, 18
 Ku-band, 6 transponders
 Meteo radiometer
 CCD camera
 Meteo Data relay transponder
 Sasar search and rescue

• **GSAT-2** (2003-18A)

GSAT-2 launch mass was 1823 kg including 840 kg of MMH/MON-3. Size 2.4 x 1.6 x 1.5m with 9.6m span. Launch 2003 May by GSLV-D2 into GTO; LAM to GEO at 48E.

D2 had extra prop in stage 1, improved strap-on and stage 2 engines. Mass 414t at launch. The S139 first stage has four L40H strap-ons. GS2 is 11.6l 2.8d with 39.3t prop of UH25/N2O4 and 804 kN thrust. GS3 is cryo, 8.7l 2.9dia.

Launch from SDSC-SHAR (Satish Dhawan Space Center). Azimuth 104 deg.

GSAT 2

Date	Time	Event	Orbit
2003 May 8	1128	Launch by GSLV D2	
		T-4.8s L40H ignite	
		T+0:0 S139 ignite	
		T+1:47 S139 burnout	
		T+2:29 L40H burnout 69km	
		T+2:30? GS-2 MES	
		T+2:33? S139 sep	
		T+3:48? Fairing	
		T+4:46? GS-2 MECO	
		T+4:50 GS-2 sep 131 km	
	1132	T+4:50 GS-3 burn 11:45 5.4 km/s	
	1144	T+16:35? GS-3 MECO	
	1144	T+16:37 GS3 sep 198 km	180 x 36000
2003 May 9		LAM-1	8850 x 36000 x 7.4
2003 May 9			801.1 8826 x 35562 x 7.4
2003 May 10	0600	LAM-2 41min	1384.0 34000 x 36000 x 0.3
2003 May 11	0520	LAM 79s	
2003 May 11			1436.81 33601 x 37999 x 0.3
2003 May 12		Solar array deploy	
2003 May 23			1436.13 35782 x 35791 x 0.0 GEO 48.0E
2003 May 27			1436.11 35783 x 35790 x 0.0 GEO 48.0E
2003 Dec 19			1436.15 35713 x 35861 x 0.1 GEO 48.0E

GSAT 2

Date	Time	Event	Orbit
2004 Feb 11			1436.08 35775 x 35797 x 0.0 GEO 48.0E

PAYLOAD

	C-band transponders, 4
	Ku-band transponders, 2
	S-band/C-band MSS mobile service payload
TRDM	Total Radiation Dose Monitor
SCM	Surface Charge Monitor
SOXS	Solar X-ray Spectrometer, 4 keV- 10 MeV phoswich detector
CRABEX	Coherent Radio Beacon Experiment, for ionospheric studies
	440N LAM
	RCS, 6 x 22N

• **Insat 3E** (2003-43E)

The final satellite in the Insat 3 series was launched by Ariane in Sep 2003. Mass 2750 kg at launch, 1181 kg dry. Size 2.0 x 1.8 x 2.8m with 15.4m span.

Insat 3E

Date	Time	Event	Orbit
2003 Sep 27	2314:46	T+0:07 Launch by Ariane 5G	
		T+2:21 EAP sep	
		T+3:10 Short Fairing A5	
	2323:30	T+9:51 EPC MECO	
	2323:36	T+9:57 EPC sep	100.48 51 x 1512 x 7.3
	2323:43	T+10:04 EADS/Astrium EPS burn	
	2339:35	T+26:56 EPS MECO	
	2343:40	T+29:01 Insat 3E sep	666? x 36000? x 7.0
2003 Sep 29	0127	LAM-1	941.00 14960 x 35900 x 1.9
2003 Sep 30	0908	LAM-2	1365.0? 33000 x 35750 x 0.14
2003 Oct 1	0808	LAM-3 186s; 510 kg prop left, 1082 kg used	1426m 35500? x 35700? x 0.1
2003 Oct 1	0930	Deploy solar arrays	
2003 Oct 8			1427.25 35489 x 35737 x 0.1 GEO 51.2E+2.2E
2003 Oct 19			1436.06 35773 x 35797 x 0.1 GEO 52.0E
2004 Jul 19			1436.05 35762 x 35808 x 0.1 GEO 55.0E

PAYLOAD

	C-band transponders, 24
	C-band transponders, extended, 12
	LAM, 440N MMH/MON-3, and 8 x 10N, 8x 22N thrusters

• **EDUSAT** (2004-36A)

Edusat (GSAT-3) launch in 2004 Sep. Launch mass 1950 kg, 820 kg dry. 440N ISRO LAM. 2.4 x 1.6 x 1.15m bus with 10.9m solar panel span.

EDUSAT

Date	Time	Event	Orbit
2004 Sep 20	1031	Launch by GSLV-F-01	SDSC
		T+1:44 Stage 1 burnout	
		T+2:30 SOM burnout	
		T+2:30 Stage 2 burn	
		T+3:47 Fairing sep 115 km	
		T+4:48 Stage 2 burnout	
		T+5:04 Stage 3 MES	

EDUSAT

Date	Time	Event	Orbit
	1047	T+16:39 Stage 3 MECO	
	1047	T+16:54 Stage 3 separation	162 x 35814 x 19.3
2004 Sep 21	0218	LAM-1 49:56	8800 x 36000 x 7.2



Table 32: I

Payload	Name	Launch Veh.	Site	Launch Date	Reentry Date	Dur	Orbit	Designation
nsat 1A	Insat 1A	Delta 3910/PAM-D	CC LC17	1982 Apr 10	1982 Sep 4	0.4yr	35394 x 36178 x 0.5 GEO 74E	1982-31A
Insat 1B	Insat 1B	Shuttle OV-099 (STS-8)	KSC LC39A	1983 Aug 31	1993 Aug	10.0yr	35767 x 35808 x 0.0 GEO 74E	1983-89B
Insat 1C	Insat 1C	Ariane	CSG	1988 Jul 22	1989 Dec	1.4yr	35763 x 35811 x 0.1 GEO 94E	1988-63A
Insat 1D	Insat 1D	Delta 4925	CC LC17	1990 Jun 12	2002 May?	11.9yr	35754 x 35807 x 0.2 GEO 83E	1990-51A
Insat 2A	Insat 2A	Ariane 44L	CSG ELA2	1992 Jul 9	2002 May	9.8yr	35770 x 35802 x 0.2 GEO 74E	1992-41A
Insat 2B	Insat 2B	Ariane 44L	CSG ELA2	1993 Jul 22	2004 Jan	10.5 yr	35769 x 35807 x 0.2 GEO 93E	1993-48B
Insat 2C	Insat 2C	Ariane	CSG ELA2	1995 Dec 6	2003 Jul 28	7.7yr	35756 x 35805 x 0.0 GEO 93E	1995-67B
Insat 2D	Insat 2D	Ariane 44LP	CSG ELA2	1997 Jun 3	1997 Oct 5	0.3yr	35742 x 35829 x 0.2 GEO 73E	1997-27B
Insat 2E	Insat 2E	Ariane 42P	CSG ELA2	1999 Apr 2			35767 x 35805 x 0.1 GEO 83E	1999-16A
Insat 3B	Insat 3B	Ariane 5	CSG ELA3	2000 Mar 21			35767 x 35804 x 0.1 GEO 83E	2000-16B
Insat 3C	Insat 3C	Ariane 42L	CSG ELA2	2002 Jan 23				2002-02A
Insat 3A	Insat 3A	Ariane 5	CSG ELA3	2003 Apr 9				2003-13A
Insat 3E	Insat 3E	Ariane 5	CSG ELA3	2003 Sep 27				2003-43E
METSAT	Kalpana 1	PSLV	SHAR	2002 Sep 12				2002-43A
GSAT 1	GSAT 1	GSLV	SHAR	2001 Apr 18	2002?	1 yr?	33841 x 35797 x 0.9	2001-15A
GSAT 2	GSAT 2	GSLV	SHAR	2003 May 8			35774 x 35798 x 0.1 GEO 48E	2003-18A
EDUSAT	EDUSAT	GSLV-F-01	SDSC	2004 Sep 20				2004-36A

1.6 IRS satellites

The Indian Remote Sensing Satellites (IRS) were built by ISRO to study the natural resources of India.

• IRS-1A (1988-21A)

IRS-1A took off from Baykonur aboard a Vostok 8A92M on a southbound trajectory to polar sun-synchronous orbit. Control from Bangalore. Launch mass was 975 kg.

If like later IRS, the bus was 1.6 x 1.6 x 1.1m with solar panel span about 12m?

IRS-1A			
Date	Time	Event	Orbit
1988 Mar 17	0643:30	Launch by Vostok 8A92M	KB LC31
	0645:30	Blok-BVGD sep (T+2:00)	
	0646:30	Shroud sep (T+3:00), 160 km	
	0648:40	Blok-A cutoff, Blok-E burn (T+5:10)	
	0654:30	Blok-E cutoff (T+11:00)	
	0654:40	Payload release (T+11:10), Blok-E sep motor	
1991		Still operating	
1995 Mar 17		Retired to standby status	

PAYLOAD

Radiometers
 LISS Cameras Linear imaging self scanning CCD
 LISS 1: 72m res, 148 km swath, 4000-9000A in 4 bands
 LISS 2: 36m res, 74 km swath, 4000-9000A in 4 bands
 Hydrazine thrusters, 1N, 80 kg prop

• IRS-1B (1991-61A)

The IRS-1B satellite had a mass of 990 kg. Its cameras had a 32-m resolution. The satellite was launched with the 8A92M rocket (Vostok-2M) from Baykonur, with NPO Lavochkin providing launch preparation services and Glavkosmos providing the interface. Control was from Bangalore.

In 2001 the IRS-1B cameras were still operating well and the spacecraft was being used for systems tests.

IRS-1B			
Date	Time	Event	Orbit
1991 Aug 29	0648	Launch by Vostok	KB
	0650?	Blok-BVGD sep (T+2:00)	
	0651?	Shroud sep (T+3:00), 160 km	
	0653?	Blok-A cutoff, Blok-E burn (T+5:10)	
	0659?	Blok-E cutoff (T+11:00)	
	0659?	Payload release (T+11:10), Blok-E sep motor	
1991 Sep 6	0000		102.79 862 x 918 x 99.2
2001 Aug 29		Still op	

PAYLOAD

Radiometers
 LISS-2 CCD Cameras 32m res

• IRS-P1 (1993-F03)

The IRS engineering model, IRS-1E, was launched on a test flight of the PSLV rocket. It was also known as IRS-P1.

During stage 2 separation, the vehicle pitched incorrectly, and although the remaining stages fired correctly, the satellite failed to reach orbit. [?],[?] Launch mass was 846 kg.

Delta-V for stage 4 was expected to be $3020 \ln(3796/1796) = 2260$ m/s. I therefore estimate an orbit of about -3300 x 348 km.

IRS-1E/IRS-P1			
Date	Time	Event	Orbit
1993 Sep 20	0512	Launch by PSLV-D1	SHAR
		PSOM sep	
		Stage 1 sep	
		T+1:36 Stage 2 burn	
		T+2:25 Fairing sep	
	0516	T+4:23 St 2 MECO	
	0516	T+4:24 St 2 sep	
		Stage 2 sep pitch anomaly	
	0516	T+4:25 Stage 3 burn 250 km 3.83 km/s	
	0519?	Stage 4 burn 80s burn	
	0519?	Apogee, 349 km	-3300? x 348 x 98.7
	0526?	Reentry over 77E 22S?	
		Impact	

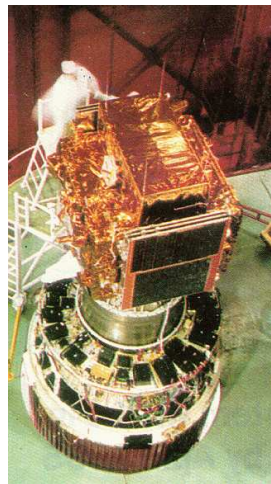
PAYLOAD

LISS-II Linear Imaging Self Scanner ISRO camera
 MEOSs German stereo imaging system Monocular Electro Optical Stereo Scanner
 CO2 band Earth radiance monitor

• IRS-P2

(1994-68A)

The IRS P2 satellite was launched aboard the second PSLV test flight. PSLV-D2 took off from Sriharikota on 1994 Oct 15. The 805 kg satellite entered polar orbit successfully.



IRS-P2			
Date	Time	Event	Orbit
1994 Oct 15	0505	Launch by PSLV-D2	SHAR
		T+00:30 PSOM 5-6 ignite	
		T+00:54 PSOM 1-4 cutoff	
		T+01:18 PSOM 1-4 sep	
		T+01:19 PSOM 5-6 cutoff	

IRS-P2

Date	Time	Event	Orbit
		T+01:30 PSOM 5-6 sep	
	0506	T+01:43 PS-1 cutoff and sep	
	0506	T+1:44? PS2 burn 2:29	
	0509	T+4:13? PS2 burnout	
	0509	PS2 sep	
	0509	T+4:15? PS3 burn 78s	
	0510	T+5:33? PS3 burnout	
	0516?	T+11:23? PS4 burn, 397s	-4100? x 818 x 98.7
	0522?	T+17:51? PS4 burnout	
	0522	PS4 sep	
1994 Oct 17			101.74 798 x 883 x 98.7

PAYLOAD

LISS-II Linear Imaging Self Scanner ISRO camera

• **IRS-1C** (1995-72A)

IRS-1C was the first of an improved generation of IRS satellites, placed in a 10:30 local time sun-synchronous orbit. Mass was 1350 kg launch, 1250 kg on orbit. [?] This was the first launch by a Molniya 8K78M into sun-synchronous orbit; the Blok-I stage was suborbital and the Blok-2BL fourth stage fired to circularize the orbit. [?] Bus was 1.6 x 1.6 x 1.1m with solar panel span about 12m?

IRS-1C

Date	Time	Event	Orbit
1995 Dec 28	0645:18	Launch by Molniya 8K78M	KB LC31
	0647:18	Blok-BVGD sep. 60 km (T+2:00)	
	0648:57	Fairing sep, 210 km (T+3:39)	
	0649:21	Blok A sep, 252 km (T+4:02)	
	0653:24	Blok I sep, 604 km (T+8:05)	-4487 x 803 x 97.94
	0656:40	BOZ ignition, (T+11:21)	
	0657	Blok 2BL ignition	
	0657:20	BOZ separation, 2BL at 0.75 thrust, 798 km (T+12:01)	
	0700:12	Blok 2BL cutoff (T+14:53), 804 km	
	0700:19	Blok 2BL sep (T+15:01)	101.1 805 x 817 x 98.6
	0710:20	Skipper sep	
1996 Jan 1		Orbit raise	816 x 818 km x 98.6
1996 Jan 5		Cameras switched on	

PAYLOAD

PAN	6-m res panchromatic camera, swath 70 km
LISS-3	23-m res multispectral camera, Linear Imaging Self Scanner. Visible, near IR band; 70.5m res SWIR channel.
WFS	Wide Field Sensor, Wide angle multispectral camera with 189m res.

• **IRS-P3** (1996-17A)

IRS-P3 was launched by PSLV in Mar 1996. Mass of the satellite was 922 kg. As well as the remote sensing instruments, it carried an X-ray astronomy payload. Three proportional counters studied variable X-ray sources in the 2-18 keV band. The first reported results [?] were measurements of the X-ray pulsar GX1+4 and the superluminal transient GRS 1915+105.

IRS-P3

Date	Time	Event	Orbit
------	------	-------	-------

IRS-P3

Date	Time	Event	Orbit
1996 Mar 21	0453	Launch by PSLV (D3)	SHAR
		T+00:30 PSOM 5-6 ignite	
		T+00:54 PSOM 1-4 cutoff	
		T+01:18 PSOM 1-4 sep	
		T+01:19 PSOM 5-6 cutoff	
		T+01:30 PSOM 5-6 sep	
	0454	T+01:43 PS-1 cutoff and sep	
	0454	T+1:44? PS2 burn 2:29	
	0457	T+4:13? PS2 burnout	
	0457	PS2 sep	
	0457	T+4:15? PS3 burn 78s	
	0458	T+5:33? PS3 burnout	
	0458?	PS-4 burn	
	0500?	PS-4 sep (or 0504?)	802 x 848 x 98.8

PAYLOAD

WiFS	Wide Field Sensor
MOESS	Modular Opto-electronic scanner (3)
IXAE	Indian X-ray Astronomy Experiment: Proportional counters (3), 2 x 2 deg field collimator, 1200 sq cm, 2-18 keV.

• **IRS-1D** (1997-57A)

IRS-1D is a duplicate of IRS-1C, with a LISS-3 sensor and a wide field sensor. It was launched by PSLV but the fourth stage shut down early with a loss of pressure, and the satellite was left in an elliptical orbit (0.13 km/s too slow). On-board propulsion was used to reach the intended orbit. Mass is 1200 kg.

The first operational flight of PSLV was upgraded to carry a 1200 kg payload. The new S-139 first stage motor replaced the S-125. The SRB firing order was changed; previously 4 SRBs ignited at T=0 and 2 later, now 2 fire at T=0 and 4 later. [?].

IRS-1D

Date	Time	Event	Orbit
------	------	-------	-------

1997 Sep 29	0447	Launch by PSLV	
		T+00:30 PSOM 5-6 ignite	
		T+00:54 PSOM 1-4 cutoff	
		T+01:18 PSOM 1-4 sep	
		T+01:19 PSOM 5-6 cutoff	
		T+01:30 PSOM 5-6 sep	
	0449	T+01:52? PS-1 cutoff and sep	
	0449	T+01:52? PS-2 burn	
	0449	T+2:36? Fairing sep	
	0451	T+4:41? Stage 2 sep, PS-3 burn	
	0452	T+5:33? PS-3 cutoff	
	0455?	T+8:23? PS-3 sep	
	0456?	T+9:45? PS-4 burn	
	0500?	PS-4 premature MECO	
		PS-4 sep	
1997 Sep 29			95.96 308 x 822 x 98.64
1997 Oct 1			96.18 328 x 823 x 98.6
1997 Oct 6			98.53 555 x 822 x 98.6
1997 Oct 10			100.38 727 x 826 x 98.6

IRS-1D

Date	Time	Event	Orbit
1997 Oct 18			100.50 739 x 826 x 98.6
2000 Sep 29		Fully operational	

PAYLOAD

LISS-3	CCD cameras, 4 bands, 23m res vis, 70m IR.
WiFS	Wide Field Sensor, 188m res, 810 km swath.
PANC	Panchromatic camera 5.8m res, 70 km swath.

• **Oceansat** (1999-29A)

IRS-P4 was launched by PSLV. It was renamed Oceansat. Mass is 1036 kg, including (?) 84 kg of propellant. Size is 2.8 x 2.0 x 2.6m with 11.7m span.

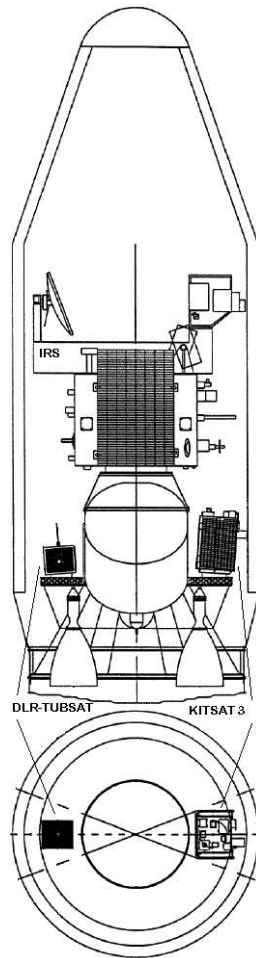


IRS-P4

Date	Time	Event	Orbit
1999 May 26	0622:00?	Launch by PSLV-C2	SHAR
		T+00:30 PSOM 5-6 ignite	
		T+00:54 PSOM 1-4 cutoff	
		T+01:18 PSOM 1-4 sep	
		T+01:19 PSOM 5-6 cutoff	
		T+01:30 PSOM 5-6 sep	
	0623	T+01:52 PS-1 cutoff and sep	
	0623	T+01:52 PS-2 burn	
		T+2:36 Fairing sep	
	0626:41	T+4:41 Stage 2 sep, PS-3 burn	
		T+5:33? PS-3 cutoff	
		T+8:23 PS-3 sep 533 km	
	0632	T+9:45 PS-4 burn 425s	
	0638	T+16:24 PS-4 MECO	
	0639	T+16:50 PS-4 sep	
	0640	T+17? KITSAT 3 sep	
	0640	T+18:31 TUBSAT sep	
1999 May 26			99.40 723 x 735 x 98.3

PAYLOAD

OCM	Vis/Near IR Ocean Color Monitor, 350m res, 1420 km swath
-----	--



MSMR Multifrequency Scanning microwave radiometer, wind speed and direction 6-21 GHz

• **TES** (2001-49A)

Technology (or Test) Evaluation Satellite.

ISRO imaging satellite to develop Indian reconnaissance capability. The TES project began in 1999 as a response to inadequate intelligence about a Pakistani incursion into Kashmir. 500 km orbit by PSLV. The satellite featured high torque reaction wheels and miniaturized power and control systems, as well as a new camera, a new propellant tank and reaction control systems. The satellite had 1-meter resolution.

Mass is 1108 kg; launched with 94 kg PROBA and 92 kg BIRD. BIRD and PROBA are mounted on side platforms on the PS4 stage.

TES

Date	Time	Event	Orbit
2001 Oct 22	0453:00	Launch by PSLV	SHAR
		T+0:25 PSOM 3-4 burn	
		T+1:06 PSOM 1-2 sep	
		T+1:30 PSOM 3-4 sep	
		T+1:52 Stage 1 sep	
		T+1:53 Stage 2 MES	
		T+2:36 Fairing	
		T+4:39 Stage 2 sep	

TES

Date	Time	Event	Orbit
	0457	T+4:40 Stage 3 burn Stage 3 MECO, coast	
	0501	T+8:20 Stage 3 sep T+8:35 Stage 4 burn	
	0508	T+15:12 Stage 4 cutoff	
	0509	T+16:10 Deploy TES	550 x 579 x 97.8
	0509:49	T+16:50 Deploy BIRD T+17? Stage 4 RCS burn 8:20	
	0520	T+27:38 Deploy Proba	

PAYLOAD

Camera, two-mirror on-axis optics, 1-m resolution
 AOCS
 Solid state recorder
 X-band phased array antenna
 Satellite positioning experiment

• **IRS-P6** (2003-46A)

IRS-P6, or Resourcesat-1, was launched on PSLV in 2003. It replaces IRS-1C and IRS-1D, carrying three improved cameras and a solid state recorder.

The PSLV-C5 launch switched the PSOM burn sequence to four ground lit and two air lit instead of the other way around.

Mass 1360 kg.

Resourcesat

Date	Time	Event	Orbit
2003 Oct 17	0452	Launch by PSLV-C5 T+0:25 Air PSOM 5-6 on T+1:08 Ground PSOM 1-4 sep T+1:30 Air PSOM sep T+1:52 PS1 sep T+1:53 PS2 on T+2:37 Fairing, at 118 km T+4:25 PS2 sep T+4:27 PS3 on T+6:29 PS3 sep T+9:00 PS4 MES	
	0509	T+17:23 PS4 MECO	
	0510	T+18:00 PS4 sep	
2003 Oct 18			101.69 802 x 875 x 98.7

PAYLOAD

LISS-3 Medium res VNIR/SWIR Multispectral camera, 4 bands; 140 km swath, 23m res
 LISS-4, High res VNIR camera, 70 km swath, 6m res; 3 bands
 AWIFS-A/B Advanced Wide Field Sensor VNIR/SWIR 370 km swath, 70m res
 Hydrazine AOCS

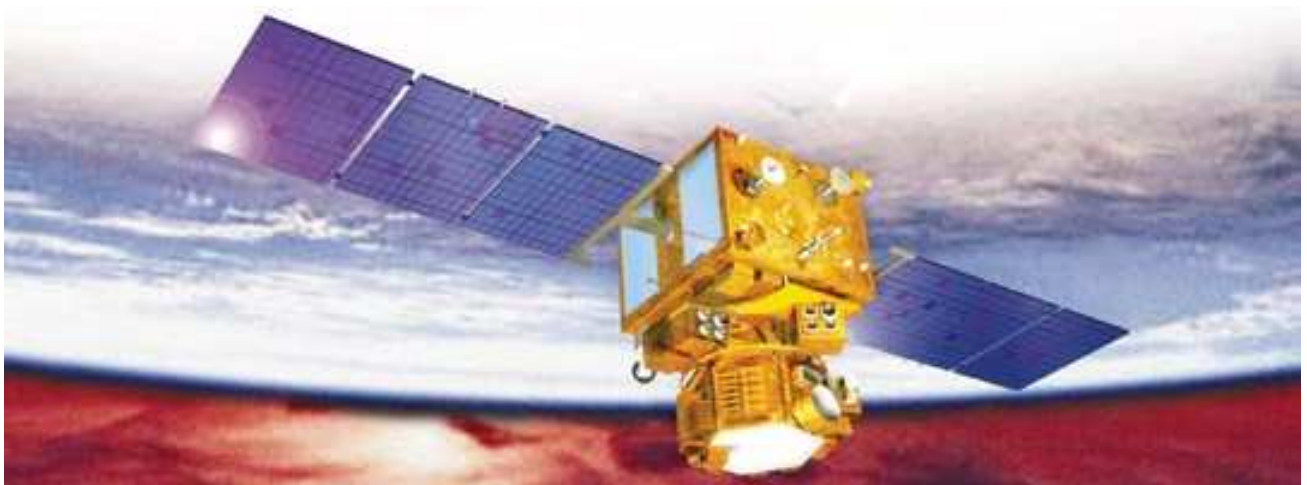


Table 43: IRS

Payload	Name	Launch Veh.	Site	Launch Date	Reentry Date	Dur	Orbit	Designation
IRS-1A	IRS-1A	Vostok	KB	1988 Mar 17	1990s?		870 x 914 x 99.0	1988-21A
IRS-1B	IRS-1B	Vostok	KB	1991 Aug 29			862 x 918 x 99.2	1991-61A
IRS-1E	IRS-P1	PSLV (D1)	SHAR	1993 Sep 20	1993 Sep 20	0	-3300? x 349 x 98.7	1993-F03
IRS-P2	IRS P2	PSLV (D2)	SHAR	1994 Oct 15			818 x 820 x 98.7	1994-68A
IRS-1C	IRS-1C	Molniya-M	KB	1995 Dec 28			816 x 818 x 98.6	1995-72A
IRS-P3	IRS P3	PSLV (D3)	SHAR	1996 Mar 21			802 x 848 x 98.8	1996-17A
IRS-1D	IRS-1D	PSLV (C1)	SHAR	1997 Sep 29			737 x 825 x 98.6	1997-57A
IRS-P4	Oceansat	PSLV (C2)	SHAR	1999 May 26			713 x 731 x 98.3	1999-29A
IRS-P6	Resourcesat	PSLV (C5)	SHAR	2003 Oct 17			818 x 820 x 98.7	2003-46A

2 Indian Rockets

2.1 Rohini

ISRO's Rohini sounding rocket program started off with input from the French. The RH-300 was a version of the Belier; the RH-560 is a modified Dragon. The RH-560 series motor has a 560mm diameter like the French Stromboli motor; the RH-300 series motor has a 310mm diameter like the Belier motor; the RH-300B booster has a 280 mm diameter like the Venus motor.

Table 44: ISRO rockets

Rocket	Length	Diam	Stages	French equivalent
RH-75	1.5	0.08	RH-75	-
RH-125	1.5	0.12	RH-125	-
Menaka	3.8	0.12	RH-125/RH-125S	-
RH-200	3.6	0.20	RH-200/RH-125	-
RH-300B	6.5	0.28	Booster/RH-300	Centaure
RH-300	4.1	0.31	RH-300	Belier
RH-300 Mk II	5.9	0.31	RH-300-II	Belier
RH-300 3-stage		0.31	RH-300/RH-200/RH-200	-
RH-560S	5.9	0.56	RH-560S	Dauphin
RH-560	8.4	0.56	RH-560/RH-300	Dragon
RH-560/300 Mk II	9.1	0.56	RH-560/RH-300-II	Dragon
RH-560B	9.9	0.56	RH-560S/RH-560	Eridan

The uprated RH 560/300 Mk 2 rocket flew in 1998 carrying DLR payloads to study the ionosphere. RH-200SV test flights (110 km apogee) in 2001.

ISRO (earlier INCOSPAR) launches of foreign-built rockets from TERLS were given TERLS-nnn designations (e.g. TERLS-8 on 1964 Jul 14 was a Judi-Dart) and ISRO designations in the same style as NASA sounding rockets (the same launch was ISRO 11.01). The ISRO designations consist of a number indicating the type of rocket (here 11 indicates Judi-Dart) and a number indicating the flight number for that rocket (01 indicating the first ISRO Judi-Dart to have a number assigned; since numbers were assigned well before launch, they were often launched out of sequence). ISRO numbers were sometimes repeated with offsets of 10: e.g. Centaure is ISRO 5, 15, 25, 35 and 45.

The different ISRO sounding rocket designations are given below, together with the number of launches from TERLS so far known in the public domain. Missing numbers in the ISRO 5 and ISRO 10 series indicate that a further 14 Centaure and 15 Nike Apache may remain to be documented.

ISRO ID	Rocket type	Number launched (ISRO-numbered)	Number launched (No ISRO no.)	Dates
ISRO 5	Centaure	23 [37]	3	1965-1980
ISRO 8	M-100	242 [296]	765	1970-1991
ISRO 10	Nike Apache	30? [45]	2	1963-1973
ISRO 11	Judi-Dart	36	1	1964-1969
ISRO 12	Arcas	6	0	1968-1970
ISRO 15	Centaure	6	-	1965-1968
ISRO 16	Skua	16	0	1970-1972
ISRO 17	Nike Tomahawk	3	0	1970
ISRO 18	Petrel	20	0	1972-1975
ISRO 20	Nike Apache	4	-	1966-1968
ISRO 21	Sandhawk Tomahawk	2	0	1972
ISRO 25	Centaure	2	-	1968
ISRO 26	Dragon	1	0	1969
ISRO 30	Nike Apache	1	-	1970
ISRO 35	Centaure	1	-	1968

ISRO 40	Nike Apache	5	-	1968-69
ISRO 45	Centaure	3	-	1967-69
RH-200	RH-200	-	2	2002
RH-300	RH-300	-	1	1978
Total		401	774	1963-1980

The Rohini statistics below give those for which launch dates are known, and those ('others') inferred from statements about the total number of a given type launched.

Of the known flights, 7 were from TERLS, 43 from Chandipur, 1 from Svalbard in the Arctic circle, and the rest from SHAR.

Table 46: Rohini flights

Type	Number known	Others	Total
RH-75	8	0	8
RH-125	0	-	0
Menaka	0	-	0
RH-200	99	-	99
RH-300B	0	-	0
RH-300	3	1	4
RH-300 Mk II	4	2	6
RH-300 3-stage	1	0	1
RH-560S	0	?	0
RH-560	8	10	18
RH-560/300 Mk II	6	1	7
RH-560B	0	?	0
Total	130	12	

Total known flights from India: $129 + 401 + 771 = 1301$. Total claimed flights (<http://www.isro.org/newsletters/spaceindia/octdec2002/webpgs/page7.htm>) are 3000, probably mostly small rockets like the RH-200.

Table 47: ISRO Ionospheric flights

1993	RH560	SHAR?		
1995	RH560	SHAR?	Test of case bonding	
1998 Apr 19	RH560/300 Mk II	SHAR		
1998 Sep 20?	RH560/300 Mk II	SHAR		
1998 Sep 29	RH560/300 Mk II	SHAR	424 km	Spread F

2.2 Small DRDO military rockets

India's DRDO (Defense Research and Devpt. Org.) has a test range at Chandipur, and also flies tests from Sriharikota. As well as the large Agni missile discussed in the SLV-3 section, DRDO has developed several smaller missiles, the largest of which is the Prithvi.

The SS-150 Prithvi is derived from the SA-2 SAM. It is 9.0m long, 1.1m dia, and uses RFNA with xylidene/triethylamine fuel. An SS-250 version has 250 km range. The SS-250 had had 5 tests by 1999.

The SS-250 air force version of Prithvi reaches 250 km, compared to the army version with 140 km. Contractor is Bharat Dynamics/Hyderabad. Dhanush is a naval version of Prithvi first tested in 2000.

Agni 1 has a 1t payload.

2.3 The SLV-3 space rocket

The SLV-3 was India's first launch vehicle, a four-stage all-solid rocket often compared to NASA's Scout.

Its successor was the ALSV, which used two solid strap-ons on the basic SLV-3, and had an uprated final stage which was tested on the last SLV-3 flight.

2.4 The Agni missile

The first stage of the SLV-3 rocket became the basis for the Agni intermediate range ballistic missile. Agni 1 has a Prithvi-derived second stage and an RV [?]. The Agni 1 second stage is liquid fuelled. The Agni II version replaces this with a solid fuel stage.

There were 4 Agni I test flights from Sriharikota. The Agni 2 launch site is at IC-4, Wheeler Island, Orissa (part of the Chandipure range), with tests landing in the Bay of Bengal.

2.5 PSLV

The second generation of ISRO rockets was much larger than SLV-3/ASLV. The PSLV (Polar Satellite Launch Vehicle) and its close relative the GSLV (Geostationary Satellite Launch Vehicle) were able to carry significant payloads into useful orbits.

The PSLV has four stages and, following in the spirit of the early Indian sounding rockets, makes use of French derived technology - in this case, from Ariane. The Vikas second stage engine is related to Ariane's Viking.

LV	Size	Mass	Config	GTO	GEO	SSO (ELEO)
PSLV	44.4m	294t	6PSOM/PS1/PS2/PS3/PS4/F	-	-	1200?

Stage	Size	Engine	T	Mass
PSOM	0.10 11.0	Solid HTPB	662 kN	1.5t?+8.6t
PS1	2.80 20.3	Solid HTPB	4628kN	27t+138t tot 229t
PS2	2.80 12.5	Vikas	725kN	5.3t+37.5t
PS3	2.08 3.5	Solid HTPB	340kN	1.2t + 7.2t
PS4	1.33 2.1	2 x PS4 Eng	14kN	920 + 2.0t

An uprated composite-case PS3 will fly on PSLV-C4. A new PS4 liquid stage will fly on PSLV-C5.

2.6 GSLV

GSLV Mark 1, to fly in mid 2000, uses the PS-1 and PS-2 stages and PSLV-derived strap-ons. The 12KRB (C-12) upper stage built by Krunichev uses a KB KhimMash KVD-1 76 kN LOX/LH2 engine. Mass of the C-12 is 2100 kg dry.

Mark 2 will use two L-40 liquid strap-ons derived from the PS-2 and using the Vikas engine. The C-12 stage will use an Indian version of the KVD-1. A Mark 3 version will use a C-20 stage with a 120-kN engine.

In 2001, the first GLV flew, a Mk 1. Mk 2 was scheduled for Oct 2003. Mk 3 would now have 1000 kN storable propellant St1, with two 2000 kN solid strap-ons and a 250 kN cryogenic stage [?]. Size is 40.5m 1 ?? dia mass 610t. Fairing is 4.0m; 4000 kg to GTO.

3 Indian launch sites

3.1 TERLS

The Thumba Equatorial Range Launch Station (TERLS) was India's earliest launch site. TERLS has 4 pads.

Pad 1 UL	Cen, N Apache
Pad 1 MSR	RH-125
Pad 2 L1,L2,L3	N Apache, N-Tom, BArcas, Skua, M-100, RH-100
Pad 3 PARCA	Centaure, Dragon
Pad 4 Rail	Judi-Dart

The Russian M-100 rocket was launched from TERLS at least 986 times between 1970 and 1990. Some of the flights were given ISRO 8.* designations; the first flight on 1970 Dec 9 was ISRO 8.01, while a flight on 1974 Feb 27 was ISRO 8.175 (also TERLS-641). Apogee was typically between 80 and 90 km.

3.2 SHAR

The Sriharikota Range on Sriharikota Island next to Lake Pulicat is the main Indian orbital range. There are four launch areas along the east coast of the island.

RH	Sounding rockets
?	Liquid booster complex
SLV	SLV and ASLV
PSLV	PSLV/GSLV complex

3.3 Chandipur

The Interim Test Range (ITR) at Chandipur-On-Sea, Orissa (21.3N 86.6E) was used for early tests of Agni. It is operated by DRDO (Defense Research and Development Organization). The Trishul surface-to-air missile is also tested at Chandipur. Chandipur is part of the Balasore Range. A new test site near Balasore, IC-4, was established in 1999 for Agni tests on Inner Wheeler Island 20.46N 87.02E (quoted as being 16 km from Balasore by DH News Service (Deccan Herald), but this is Chandipur).